CONQUEST OF DARKNESS

NIGHT VISION AND ELECTRO-OPTICS TECHNOLOGY TRANSFER

1972-1981

U. S. ARMY ELECTRONICS RESEARCH & DEVELOPMENT COMMAND
NIGHT VISION AND ELECTRO-OPTICS LABORATORY
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TECHNOLOGY TRANSFER

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and

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FOREWORD

The Night Vision and Electro-Optics Laboratory (NV&EOL) has the responsibility of enhancing the combat effectiveness of the U.S. Army by developing high-technology night vision and electro-optical devices and systems.

For almost a decade the NV&EOL has also backed the concept of *technology transfer.* In 1972, the NV&EOL became a charter member of the Federal Laboratory Consortium for Technology Transfer – an organization created to stimulate the use of Federal Government research and development advances. The NV& EOL has continued to support the goals of the Federal Laboratory Consortium, realizing that real benefits can be derived from the timely application of Army night vision and electro-optical research and development advances to non-military use.

During the past decade, the NV&EOL has seen many of its research and development efforts result in useful spinoffs in the areas of: *health and medicine, environment, space, safety, construction, facilities management, surveying, community service, law enforcement, and the biological sciences.* This report presents a short description of night vision and electro-optics fundamentals, a glimpse of the NV&EOL's research and development efforts, and a sample of the subsequent spinoffs that have resulted.

PREFACE

Did you know that the Night Vision and Electro-Optics Laboratory (NV&EOL) has developed image intensifier devices that will enable you to see clearly at night in faint starlight, infrared devices that let you see in total darkness through a process called *Thermal Imaging,* and low-energy lasers to do a variety of specialized tasks?

Many of these devices are now unclassified and are available for experimentation by U. S. government laboratories, state and local governments, universities, private industry, and other responsible groups or individuals that can effectively use these relatively new technologies to solve problems facing our modern society.

Did you know that a medical doctor borrowed one of our starlight scopes and, as a result of his technology transfer ideas and experimentation, victims of night blindness can now purchase a small image intensifier to improve their vision? Image intensifiers have also been used in eye research, in detecting tiny but potentially fatal lung tumors, and as an integral component in a handheld X-ray device.

Both the U.S. Forest Service and the Bureau of Mines have borrowed our night vision devices. The result–forest fires being fought and potential mine cave-ins being detected with the aid of thermal imaging devices. Our thermal imaging devices have also been used to detect heat loss in low income housing, water leaks in building roofs, and to pin-point defective components in electrical generation and distribution systems.

City police, Treasury agents, and the U.S. Border Patrol are among those who have borrowed and tested our devices and received our assistance. They have discovered the value of seeing in the dark–of how this new technology can help them in their important missions.

Researchers at the Gombi-Stream Research Center in Tanzania, Africa, have used our night scopes to study chimpanzee mother-infant behavior. Scientists in South America have used our scopes in researching blood-sucking vampire bats that cause economic loss by carrying rabies and preying on cattle, and Department of Agriculture scientists have used our Night Vision goggles to aid in research aimed at developing control methods for night-flying, crop-destroying insects.

This is only a sampling of how technology transfer is working in the U.S. Army Night Vision and Electro-Optics Laboratory. Technology Transfer–a process of transferring the benefits of our research and development knowledge into other useful processes, products, and programs that fill specific public and private needs. It is also the process of employing our technology for purposes other than national defense for which it was developed.

We hope that this report will give you a basic understanding of the night vision and electro-optical technology, and that the examples we have presented on the diverse uses will give you a better feel of these technologies.

The technology transfer results described in this report have evolved from the combined efforts of many individuals who have been active in: effecting technology breakthroughs, promoting technology transfer, applying the resulting advances to beneficial civilian use, and in

modifying military night-vision and electro-optic designs for new and useful purposes. The results described in this report, have evolved through the underlying support of local, state, and Federal Government activities, universities and especially U.S. industry which has made many of the devices described herein a reality.

This report is dedicated to the above individuals and organizations and to the following Night Vision and Electro-Optics Laboratory scientists and engineers, and others too numerous to mention, who have made the transfer of night vision and electro-optical technology possible: *Lawrence Acchione, William Bayse, Vincent Bly, Benton Boogher, Rudolf Buser, Edward Butcher, Louis Cameron, Charles Charleton, Carol Cutchall, Patrick Daly, Donald Dearing, Nickolas Diakidis, William Dincher, Edward Efkeman, Richard Fulton, Steve Gibson, Benjamin Goldberg, David Helm, Donald Hendrix, Jack Hildreth, Lawrence Hyer, Donald Jenkins, John Johnson, Andrew Kennedy, Isadore Kessler, Myron Klein, Jack Lee, Wilbur Liebson, Donald Looft, Jasper Lupo, Donald Merritt, Robert Milan, James Miller, Joann Olsen, Jeffrey Paul, James Perry, Clarence Pritchard, Andy Repasy, Warren Robinson, Richard Seemiller, Stanley Segal, Edward Sheehan, Jeffrey Slusher, Spurgeon Smathers, Stanley Sobezyanski, Robert Stone, Benjamin Toler, and James Updegraff.*

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I. INTRODUCTION

Purpose and Scope

The purpose of this special report, "Night Vision and Electro-Optics Technology Transfer 1972-1981," is threefold:

- To illustrate, through actual case histories, the potential for exploiting a highly developed and available military technology for solving non-military problems.
- To provide, in a layman's language, the principles behind night vision and electro-optical devices in order that an awareness may be developed relative to the potential for adopting this technology for non-military applications.
- To obtain maximum dollar return from research and development investments by applying this technology to secondary applications. This includes, but is not limited to, applications by other Government agencies, state and local governments, colleges and universities, and medical organizations.

It is desired that this summary of Technology Transfer activities within Night Vision and Electro-Optics Laboratory (NV&EOL) will benefit those who desire to explore one of the vast technological resources available within the Defense Department and the Federal Government.

Technology Transfer

The necessity for improving U.S. Army and civilian communications is always apparent. One way of pursuing this goal is through Technology Transfer—a means by which mutual benefits can be obtained by applying Army developed technology to the needs of the community. As a Technology Transfer focal point for the Department of Defense, the Night Vision and Electro-Optics Laboratory (NV&EOL) can only participate when requested to do so and when civilian sources are neither reasonably nor readily available.

Technology Transfer projects are administered as required under the auspices of the Director's office. Although no full-time personnel are assigned to this area, every effort is made to comply with each request. Technology Transfer activities have ranged from symposium presentations, general briefings, lectures, demonstrations, and technical assistance to short-term loans of unique night vision and other electro-optical equipment. Medical establishments, law enforcement agencies, colleges and universities, Federal, state and local government agencies, and industrial research firms have sought assistance regarding the application of night vision and other electro-optical devices for possible solutions to their problems and special interests.

The NV&EOL is a charter member of the Federal Laboratory Consortium for Technology Transfer and has participated in numerous activities resulting in a beneficial transfer of electro-optical information and technology to other government users as well as the private sector. The Director, NV&EOL endorses the Consortium concept, stressing the importance of exploiting the technological expertise that exists within the Laboratory for possible solutions to domestic problems.

II. NIGHT VISION ELECTRO-OPTICS OBJECTIVES

The U.S. Army's Night Vision and Electro-Optics Laboratory (NV&EOL) has the mission of enhancing the combat effectiveness of the U.S. Army. NV&EOL's scientists and engineers, working in their laboratories at Fort Belvoir, Virginia, have developed a wide spectrum of devices that provide our military forces with such benefits as the ability to "see" at night without being detected, and the ability to accurately determine ranges, and to designate targets.

The early work in night vision, which centered around the use of near-infrared devices and searchlights, has evolved into research and development of sophisticated passive image intensifiers, far-infrared viewers, and low-energy laser light sources. These devices have been developed, not only to equip individual soldiers with night vision and accurate aiming devices, but to provide armored vehicles, army aircraft, and anti-armor missile systems with integrated passive night vision and electro-optical capabilities.

The NV&EOL is involved in research and development of both night vision and electro-optical equipment. Night vision refers to technology directed toward improving sight under poor visibility conditions such as darkness or battlefield atmospheric clutter. Electro-optics refers to technology directed toward low-energy lasers used in range finding, target designation, and weapon aiming.

Although the objective of NV&EOL is to develop devices that will enhance the combat effectiveness of the U.S. Army, many of these night vision and electro-optical devices have a great potential for serving useful functions in the non-military community. Therefore, the technology behind those devices which are not classified may, as the need dictates, be transitioned into the non-military community through technology transfer.

However, before this technology can be transferred, an awareness of the technology must be made known to the non-military community. The following brief discussion is intended to provide some familiarity with the subject of night vision and electro-optic technology and to provide a glimpse of NV&EOL's work in these areas.

NIGHT VISION TECHNOLOGIES

Night Vision and the Electromagnetic Spectrum

The human eye and many man-made devices such as radios, television, and night vision devices operate at different wavelengths within a continuum that may be termed as the "spectrum of electromagnetic radiation." This spectrum of electromagnetic radiation is illustrated in Figure 1. The human eye and each of the various man-made devices are tuned to a specific wavelength or band of wavelengths within this spectrum. Each is, therefore, sensitive only to a certain portion of the spectrum.

The human eye is sensitive to "visible" light. Visible light comprises the band of electromagnetic waves from approximately 0.4 to 0.7 microns in length, where a micron equals one millionth of a meter. Night vision devices, on the other hand, are sensitive to electromagnetic wavelengths outside of this band and, in certain cases, to visible light below the eye's threshold of sight.

A night vision device is analogous to, but simpler than, an ordinary radio. A radio detects electromagnetic wavelengths or frequencies that are not detectable by the human ear. The radio processes this energy into audio frequencies, and outputs them via the radio's loudspeaker in the form of acoustic radiation (sound) detectable by the human ear.

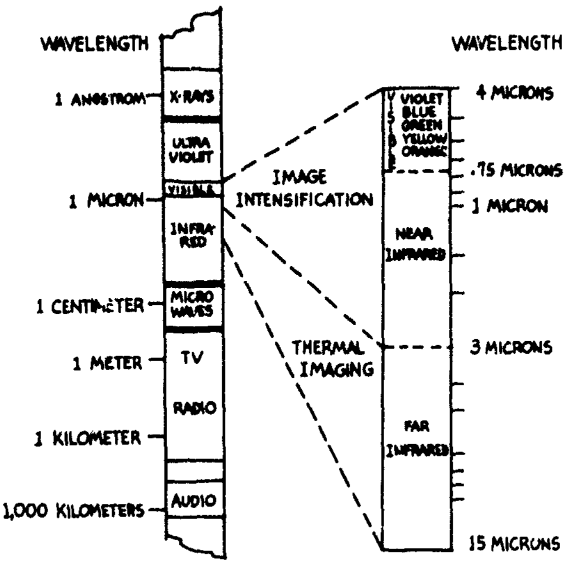


Figure 1. The Electromagnetic Spectrum

Similarly, a night vision device detects electromagnetic wavelengths or frequencies beyond the range or below the threshold of human vision; converts these electromagnetic waves into electrical energy; processes and amplifies the electrical energy; and converts it into "visible" wavelengths or frequencies via the night vision device's output phosphor screen, diode array, or cathode ray tube.

These night vision output devices can be viewed by the human eye just as a radio's loudspeaker can be heard by the human ear. The night vision device; however, is simpler than the radio because the visible wavelengths are output directly via a display whereas the audio frequencies of the radio must be converted into acoustic radiation (sound) by the loudspeaker in order to be heard.

Research and development in night vision has involved the exploitation of three basic imaging techniques–near-infrared and searchlights, image intensification, and far-infrared (thermal imaging). Each of these three techniques is described below.

Where We've Been: Near-Infrared and Searchlights

A simple near-infrared (IR) viewer system is shown in Figure 2. Invisible near-IR light, which is reflected from the viewed scene, is focused on a photoemissive surface (photocathode) of silver-oxygen-cesium which is sensitive to near-IR radiation in the 0.7 to 1.2 micron spectral band. The near-IR light striking this surface causes electrons to be emitted from the photocathode. These emitted electrons are accelerated by a high-voltage, as in a TV set, until they strike a phosphor screen on the opposite end of the tube. The phosphor screen glows with an image similar to the display of a miniature TV picture tube. An eyepiece fitted with a lens enables the viewing of this image close-up.

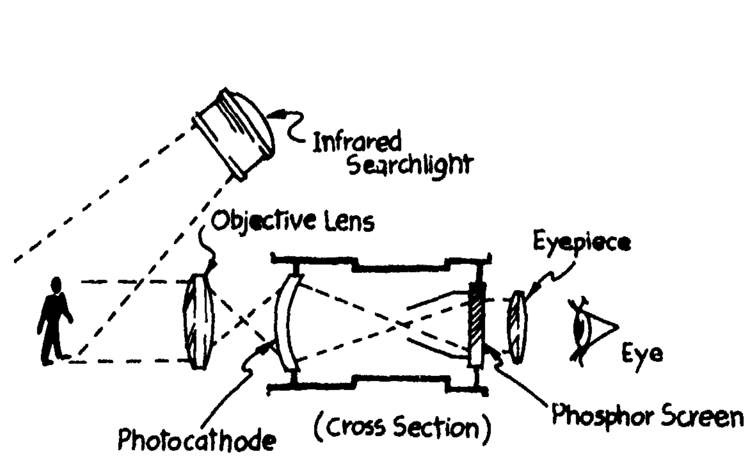


Figure 2. Infrared Viewer (WWII Vintage)

The near-infrared viewer requires that the scene to be viewed be illuminated with a near-infrared light source. Such a light source can be fabricated by simply adding a filter to a standard searchlight. The filter allows only the invisible near-infrared light to be emitted.

The near-infrared technology was first fielded during World War II. However, since near-infrared searchlights are easily detected with IR viewers, they are no longer considered effective for military use. Consequently, very little military research and development is now being conducted in near-infrared. Development of image intensifiers, described in subsequent paragraphs, has led to tne gradual phasing out of near-infrared for military use. However, many of these infrared devices can still be found in the surplus market as well as in new commerical equipment.

Although near-infrared has lost much of its military value, it has continued to offer benefits for a wide variety of civil applications. The infrared low-energy radiation is often less damaging and more penetrating than visible light. It has been used in medicine for the study of veins, skin disease, and the eye. In industry, near-IR is applied to quality control of textiles and dyeing, and pollution detection. It is also used in other applications such as: examination of forged documents and paintings, infrared spectroscopy, and in photographic darkrooms.

Where We Are Today: Image Intensification

Based on knowledge gained during the development of near-infrared systems, the Army's scientists successfully fabricated the first practical image intensifier in the late 1950s. Our nation's astronomers should be credited for their early persistence to keep this program alive—these first large and inefficient image intensifiers showed very little military potential. Image intensifiers have since proven extremely valuable in exponentially increasing the light-gathering power of telescopes. Funding transferred to the Army during those early days of research proved to be a very good investment.

Equipment utilizing image intensifier technology provides an ability to "see" during periods of low light levels by amplifying the faint moon glow and starlight conditions. Therefore, unlike near-infrared devices, image intensifiers acting passively do not require their own light sources.

Figure 3 illustrates a typical image intensifier which is actually three image intensifier vacuum tubes fiber-optically coupled together into one. The tubes use multialkali photocathodes made up of cesium-sodium-potassium-antimony. The sensitivity of these photosurfaces covers that portion of the electromagnetic band ranging from 0.4 microns, within the visible band of light, to 0.85

microns within the near-infrared band. Since the tubes include a near-infrared response, they are able to detect enemy usage of near-infrared systems while remaining undetectable by the enemy. The ability of these units to detect near-infrared light also enhances their resolution under low ambient light conditions.

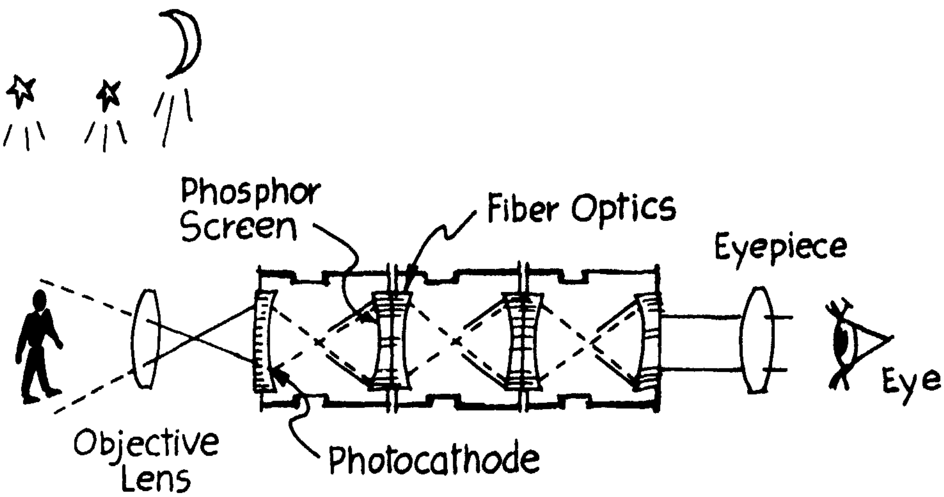


Figure 3. Image Intensifier (3-Stage)

The image intensification system operates by focusing a dim visible and near-infrared image on the front surface of the first stage fiber optics. This image is transmitted through the fiber optics to the photocathode. Electrons are emitted from the photocathode and are accelerated and focused onto the first stage's phosphor screen. These electrons are absorbed by the phosphor and their energy is radiated into a visible image. This image is then transmitted via the input fiber optics of the second stage and the process repeats. Gains of up to 100,000 have been achieved with these early systems, however, a gain of 40,000 is considered normal.

More recently, scientists have successfully fabricated advanced image intensifier devices. Figure 4 illustrates an advanced device that utilizes a vacuum tube with a photocathode and a phosphor screen as did the earlier devices; however, amplification of the image is achieved through the use of a single micro-channel plate (MCP).

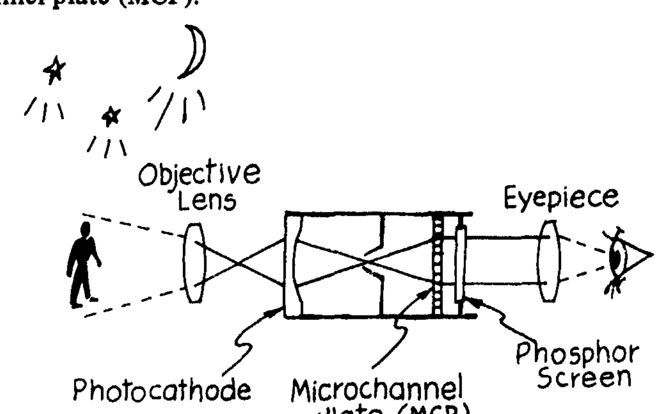


Figure 4. Advanced Image Intensifier with Microchannel Plate

The MCP is a wafer-thin slice made from a bundle of many very small hollow glass tubes which have been fused together. Each glass tube has a conductive inside surface that has secondary emission characteristics such that several electrons are emitted when struck by a single electron. When a dim-night scene is focused on the photocathode, electrons are discharged toward the inside of each tube. This forms an electron image which passes through the MCP. Each electron, striking the inside tube walls of the MCP, causes emission of secondary electrons. Thousands of these secondary electrons impinge on a phosphor screen that converts the electron image into a visible display.

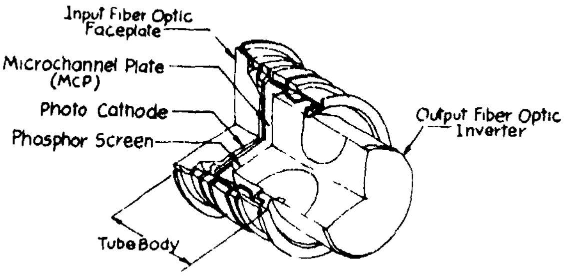


Figure 5. Advanced 18mm Image Intensifier Tube

These advanced image intensifier tubes are lighter in weight than the earlier three-stage tubes and have overcome the problems of flare caused by bright objects such as tracers, headlights and pyrotechnics.

Two relatively advanced image intensifier tube designs using the MCP principle are: the 25 mm (photocathode diameter) image intensifier tube used in small starlight scope (Figure 16) and crew served weapon sight, and the 18 mm image intensifier tube (Figure 5) used in the night vision goggles (Figure 11).

NV&EOL scientists, engineers, and technicians are continuing to develop new image intensifier tubes with photocathodes exhibiting better performance at extremely low light levels. These new image intensifier tubes will be used to improve Army night vision and will no doubt eventually find their way into the private sector.

Where We're Going: Far-Infrared

Far-infrared (thermal imaging) devices, which are capable of operating effectively under severe weather and battlefield conditions, are a relatively new addition to military operations. Laboratory far-infrared devices have existed for years; however, during the last decade, miniaturization of electro-optical and electronic components has led to the design of the present lightweight, battery-operated, high-performance systems.

Unlike image intensifiers, far-infrared viewers can "see" during total darkness by detecting and displaying small temperature differences between objects and their backgrounds (Figure 6). Many objects viewed by far-infrared emit considerable thermal (heat) radiation which passes easily through poor atmospheric conditions in the 3 to 5 and 8 to 14 micron electromagnetic bands (see Figure 1). Even objects of relatively low temperatures are often "hot" enough, in respect to their background, to be detected by sensitive far-infrared devices (see Appendix 1).

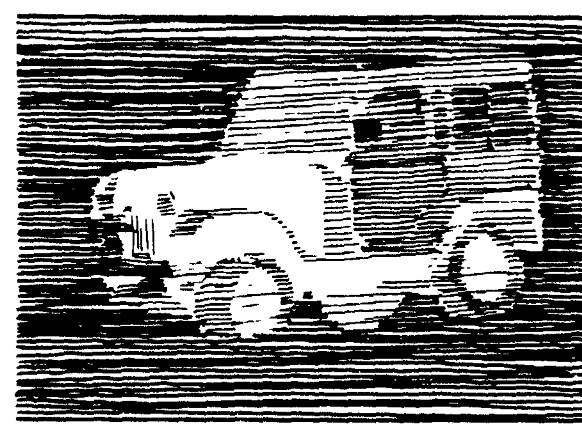


Figure 6. Night Scene, Infrared Viewer

High performance far-infrared devices are presently much more complex than the previously described image intensifiers. Intensive research, however, is being accomplished at NV&EOL and other laboratories to reduce their complexity and to improve far-infrared optics, cryogenic cooling, detector sensitivity, electronic signal processing, and visual displays.

The far-infrared viewer (Figure 7) typically utilizes a germanium lens to collect and focus the far-infrared image onto a special thermal-sensitive detector array. The detector array is super-cooled to temperatures as low as -321°F. A scanning mirror sweeps the focused thermal scene across the array of super-cooled detectors. Each detector emits an electrical signal proportional to the temperature of the portion of the scene that has been swept across it. These signals are amplified and are reconstructed into a visible scene via a light-emitting diode (LED) array. The scene is viewed through an eyepiece, providing the user with an image of the scene—even in total darkness. These systems are commonly referred to as "FLIRS" (Forward Looking Infrared Systems).

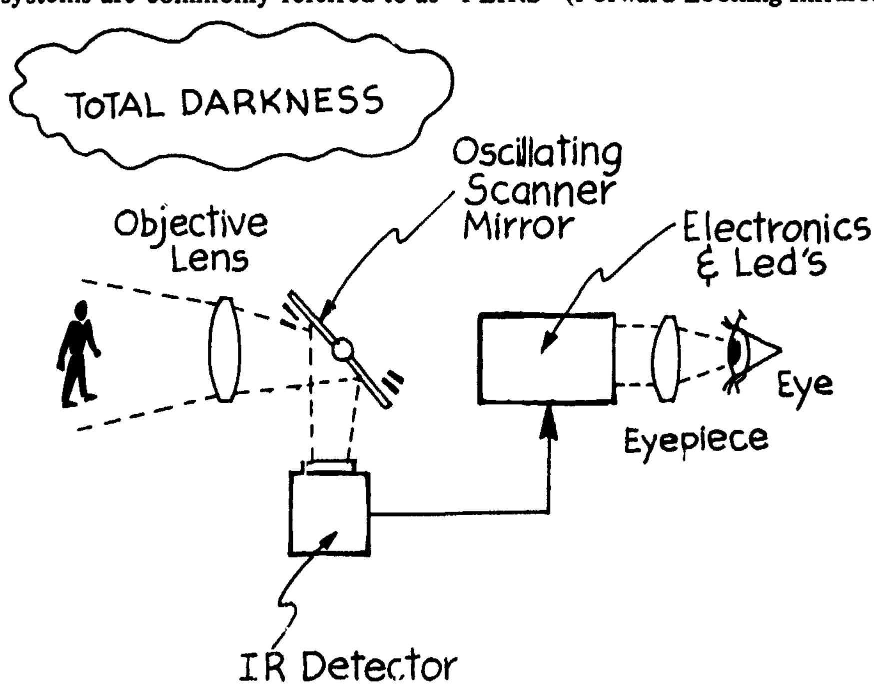


Figure 7. Advanced Infrared Viewer

NV&EOL is expending a considerable effort in the further development and exploitation of the far-infrared technology. New sensors with thousands of detector elements, compared to the 180-element detector arrays used in existing equipment, will greatly extend the sensitivity and resolution of far-infrared equipment. Work is also being directed at developing less complex and less expensive far-infrared devices with lower power and cooling requirements. The future potential of far-infrared will dramatically enhance our ability to "see" through adverse conditions and during total darkness.

ELECTRO-OPTICS TECHNOLOGIES

LASER Operation

"LASER" stands for Light Amplification by Stimulated Emission of Radiation. In other words, the LASER produces and amplifies light. LASERS have distinct properties unlike other light sources; they produce a very highly intense, non-divergent, coherent, monochromatic light beam.

As we discussed in the previous section on night vision, light forms a portion of the electromagnetic spectrum in the visual, infrared or ultraviolet areas (see Figure 1). A LASER produces uniform light which can be represented as a very discrete frequency within one of these areas.

The first LASERS were made with a ruby rod (see Figure 8). Typically then, LASERS operated as follows: A ruby rod is ground flat, polished and silvered to produce a mirror at each end. One end however is more transmissive than the other. A flash tube, similar to a strobe light, is then placed or wound around the ruby rod.

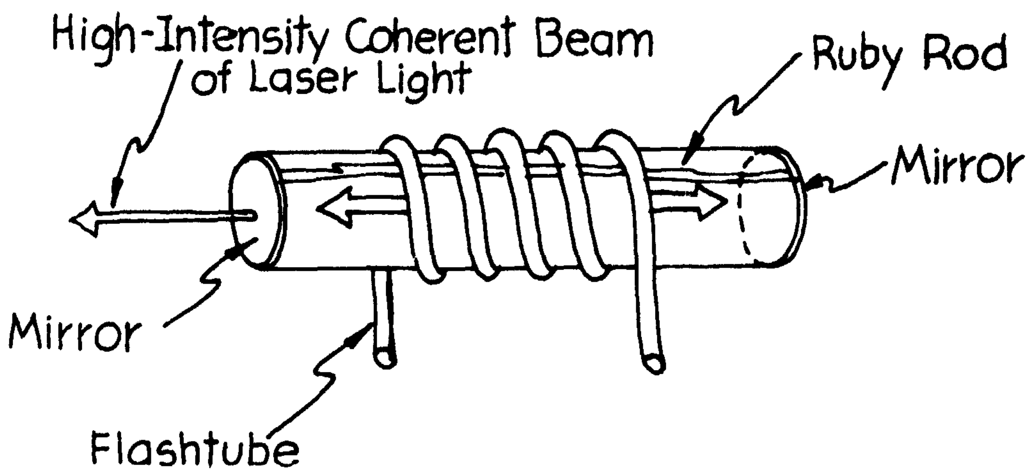


Figure 8. Typical Ruby Laser

The flash tube produces energy in the form of light pulses. This energy is absorbed by the ruby. Much of the energy is lost as heat and stray light; however, some of the energy forms a light beam parallel to the axis of the ruby. The mirrored ends reflect this beam back and forth causing it to pick up energy until some of the energy is intense enough to pass through the more transmissive mirror surface at the one end of the ruby rod. This energy is in the form of a high intensity, coherent beam of red light.

Since the first demonstration of a ruby LASER in 1960, there have been other types of LASERS developed which operate, in certain respects, in a manner similar to the ruby LASER. These LASERS include: Solid State LASERS, Semi-conductor LASERS, Gas LASERS and others.

Low Energy LASER Development

LASER technologists are continuing to search for efficient eyesafe lasers. This has led to the development of holium-doped yitrium-lithium fluoride (HO:YLF) materials. This laser material offers an eye-safe alternative for various laser rangefinders and target designator training device applications. Because they operate at a wavelength of 2.06 microns, the eyesafe lasers are far less dangerous to the eye than other lasers, such as neodymium: YAG. An eyesafe demonstration model of a LASER rangefinder has been built in a configuration similar to the U.S. Army Hand Held LASER Range Finder.

Possible civilian applications of the HO:YLF eyesafe LASER include instrumentation for long-range surveys and instrumentation for cloud height and visual range estimation.

The initial discovery of injection LASERS (defined as electrically driven semi-conductor devices which convert the diode current to optical energy) has led to further potential military and civilian applications ranging from fiber optics guided missiles, and helicopter-borne terrain avoidance systems to telephone switching training devices. Additional civilian applications include the use of injection lasers in the intrusion alarm industry and in fiber-optic communication systems which promise low cost, reliable, interference-free, secure communications between telephone and data subscribers.

MILITARY APPLICATIONS

The NV&EOL has the responsibility of developing night vision and electro-optic infantry systems, armor systems, anti-armor systems, and aviation systems. To meet these responsibilities, the NV&EOL has utilized and integrated the previously discussed night vision and electro-optic technologies as required to produce effective systems as described below.

Infantry Systems

The infantryman's equipment requirements are unique; unlike other combat arms elements of the Army, the foot soldier must carry everything he needs, including batteries and accessory equipment for his electro-optical equipment. Accordingly, lightweight and high performance are principal design factors for NV&EOL Infantry developments.

Since the mid-1960s, Army research has been directed towards development of lightweight rifle and crew-served weapon telescopes enabling the soldier full-range performance at night. Aside from the sighting requirements for small arms, NV&EOL is also responsible for developing night driving equipment as well as general purpose night vision aids for the Infantry.

Among NV&EOL's past accomplishments in this area are the Night Vision Goggles, a system originally developed for night driving of wheeled vehicles but currently used for aircraft pilotage and other tasks.

Long range equipment for general surveillance is also a long-standing Infantry requirement. Early night observation devices utilized image intensification techniques; currently, thermal systems with much longer ranges are being fielded to meet this requirement. This new equipment is designed around NV&EOL's "Common Modules," a set of building-block components used in a variety of different night vision devices for Infantry, Armor, Anti-armor and Aviation requirements.

Armor Systems

Two fundamental vision requirements exist for the Army's armored fleet: driving and fire control. In the past, both of these requirements were met with active, near infrared periscopes that could be easily detected with image intensifiers or near infrared equipment. However, equipment replacing these older periscopes is passive giving tankers more security from detection while driving and acquiring targets.

The new driver's periscope utilizes the same image intensifier tube used in the rifle and crew-served telescopes for infantry applications. Since the tube is by far the most expensive part of the viewer, the selection of a standard image intensifier tube has minimized cost factors. Also, the new periscope, aside from being a far superior driving aid, will also detect enemy usage of near infrared driving and fire control systems.

Thermal techniques will meet the armor community's requirement for fire control in the improved M60 vehicles and the M-1 tanks. The same "common modules" used in other infantry, anti-armor and aviation systems will be used in the "Tank Thermal Sight" for on-board fire control. This new periscope will see much farther than current equipment and also penetrate smoke, light fog and dust—a long-standing armor requirement. Because thermal techniques offer an all-weather capability, research is being conducted to develop a thermal driver's periscope which may replace the current image-intensification driver's periscopes.

Anti-Armor Systems

The Army munitions inventory contains two high performance anti-tank systems: TOW and Dragon. Innovations at NV&EOL have made it feasible to incorporate new thermal "common module" night sights with these two weapon systems.

Anti-armor gunners, using the TOW or Dragon electro-optical systems, can easily detect, recognize, and guide their missiles to targets at the full range of the missile during the night. Since these systems see by displaying small temperature differences between targets and their background, these sights can also be used during the day when atmospheric obstacles render the day-sight inoperative.

Aviation Systems

Design of pilotage and fire control equipment must take into consideration that the pilot's attention must be focused on flying the aircraft. It must also provide the pilot with flight information as well as a clear view of the battlefield.

Current requirements for the Army's new Attack Helicopter call for a pilotage as well as a target acquisition sensor. NV&EOL's plan to meet these requirements is centered around two devices: Pilots Night Vision System (PNVS), and the Target Acquisition Designation System (TADS).

The PNVS consists of a thermal sensor mounted on the nose of the aircraft with a Helmet Mounted Display (HMD) for the pilot. The sensor provides sufficient field of view and mobility for pilotage. Since the sensor is directly coupled to the HMD, the sensor turns as the pilot turns his head.

The TADS consists of a second thermal system mounted on the nose of the aircraft coupled with a small TV type display for the gunner. TADS has different fields of view for target search, recognition and engagement and can also be displayed, on command, to the pilot.

THE FUTURE

Where Are We Going?

Technology is moving at such a rapid pace that equipment of the future looks "star-warish." In the image intensifier field, new photo-emissive surfaces yielding much higher efficiencies are being developed. Infrared technology advances in image processing and detector fabrication are expected to provide thermal systems with much greater sensitivity than current equipment, and more efficient low energy Lasers are being developed.

Scientists are also considering development of synergistic systems employing distinctively different imaging techniques such as wide-band night vision devices operating from the visible to the far limits of the infrared portions of the electromagnetic spectrum.

Our Role In Technology Transfer

One of the real prizes for the Army Research and Development community is to also have our military technological advances applied to peaceful, non-military applications. It is indeed rewarding for NV&EOL to be a part of this "technology exploitation" and to play a role assisting others in solving problems facing our modern society by providing night vision and electro-optics expertise.

As much as we would like to, the NV&EOL may not, however, provide assistance unless it is within the guidelines established in AR70-57 "Military-Civilian Technology Transfer" and it does not otherwise interfere with our defense mission.

III. NIGHT VISION AND ELECTRO-OPTICS SPINOFFS

HEALTH AND MEDICINE

Aid to Victims of Night Blindness

The Night Viewing Pocketscope, a spinoff from the Night Vision Goggles, is now available to victims of night blindness. As the Night Vision Goggles became perfected, the concept of a hand-held, monocular image intensifier or "Pocketscope" was made a reality when the Army made the first unit in-house. Working closely with U.S. Industry, a civilian application was soon found in the medical field to aid thousands of Americans suffering from the night-blinding disease Retinitis Pigmentosa or RP.

Since the natural vision process of RP victims slowly degenerates to a point where they are unable to see at any light level below sunlight, seeing in darkness appeared hopeless; however, an ophthamologist studying the problem at the Harvard Medical School tested a Pocketscope and determined that RP victims could regain at least part of their night vision by using the Pocketscope.

Figure 9. Commercial Night-Vision Pocketscope

A foundation has since been established wherein victims of this disease can purchase a prescription Pocketscope that will enable them to see again during periods of darkness. Developed by the Army, the Pocketscope is now being commercially manufactured and is available to RP victims. (See Figure 9.)

The Night Viewing Pocketscope has a 1X magnification, a field-of-view of 40 degrees, can be focused from 25cm to infinity and has a brightness gain up to 800. The Pocketscope is powered by rechargeable nickel-cadmium batteries which will operate for approximately 5 hours between chargings.

Obstacle Avoidance for the Blind

The laser community has devised a concept for using laser technology to provide a simple device for obstacle avoidance which it presented to the National Foundation for the Blind in June 1978. The meeting, entitled "Mobility Aids for the Blind," explored applications of NV&EOL technology developments for providing simple, low cost aids for the blind. One commercial application has resulted in a laser blind cane. This aid detects laser light signals, emitted by the cane, which are reflected back to the cane's detector from nearby obstacles. Upon detection the laser blind cane provides the user with a warning.

Eye Research and Image Intensifiers

At Purdue University, West Lafayette, Indiana, scientists have been successful in utilizing image intensifier tubes in the study of retina rod cells. Since rods are sensitive to visible light, infrared light is better suited for illumination during observations. To accomplish this, a pair of image intensifier tubes was fitted onto a dissecting microscope and successfully used for these observations.

At Vanderbilt University, Nashville, Tennessee, image intensifier tubes, mounted on top of a trinocular-head microscope, were successfully and routinely used in photoreceptor cell research.

University of Pennsylvania researchers at Philadelphia, Pennsylvania, utilized an early 3-stage image intensifier during the study of the chemical and electrical activity of visual receptors that are set off by light. This enabled preparatory work to be accomplished using infrared illumination. The image intensifier also enabled the observation of weak visual fluorescence from visual cells utilizing small doses of ultra-violet activating light.

Low Intensity X-Ray

The Night Vision and Electro-Optics Laboratory and NASA's Goddard Space Flight Center, Greenbelt, Maryland collaborated with the National Institutes of Health and Dental Care, Bethesda, Maryland, to develop a unique low intensity X-ray imaging device or Lixiscope. The Lixiscope is a small portable X-ray device which uses basic technologies pioneered and developed by NV&EOL under its image intensification program. The Lixiscope has not only received national interest, but has been acclaimed by the medical, scientific, and industrial communities.

This collaborative effort was informally initiated in late 1976 through the loan by NV&EOL of a microchannel plate image intensifier tube to NASA for the purpose of performing laboratory tests of its sensitivity to X-ray radiation.

During these laboratory tests, it became apparent that a low intensity X-ray image could be converted to a visible image with available off-the-shelf NV&EOL image intensifier tubes. NASA scientists, therefore, concluded that a device of this type would offer advantages of low power, portability, reduced X-ray dosage, and handheld features which were not available from any other type of conventional X-ray system.

NASA stressed that the Lixiscope's unusual and unique features were made possible as a direct result of the interchange of technology; namely, the microchannel plate image intensifier tube which was compact, of high resolution and gain, and operated with a miniature power supply. The heart of the image intensifier tube is a microchannel plate which amplifies electron images by many orders of magnitude, conceivably one million times.

NV&EOL fabricated the prototype portable X-ray device (Lixiscope) using a NASA supplied radioscope of iodine 125 in a point source configuration.

The Lixiscope offers potential applications as: a handheld instrument for dental radiography giving real-time observation in orthodontic procedures; a portable instrument for the preliminary diagnosis of extreme bone injuries; a handheld quality control inspection device; a device for analysis in the electrical, mechanical, biological, and chemical fields; and a security instrument for inspection of packages.

Egg Fertilization Studies

Researchers at the University of California, Los Angeles (UCLA) borrowed a 25mm image intensifier tube from NV&EOL to research the distribution of free calcium within living cells (a medaka egg–the medaka is a fresh water fish). Free calcium is visualized by introducing the chemiluminescent photo-protein, aequarin, into the cells and then observing the pattern of emitted light. Since this light is of very low intensity, it was necessary to use an image intensifier to observe it.

The magnified image of the medaka egg was focused by a microscope on the cathode of the 25mm image intensifier tube. The output phosphor of the tube was viewed by a vidicon camera. The camera image was presented, in real time, on a television monitor and simultaneously recorded on magnetic videotape. Photographs for analysis were taken from the videotape playbacks.

As a result of these experiments, the researchers concluded that the fertilization wave in the medaka egg is propagated by calcium-simulated calcium release primarily from some internal sources other than the large cortical vesicles. A comparison of the characteristics of the exocytotic wave in the medaka with that in other eggs, particularly in echinodum eggs, suggested that such a propagated calcium wave is a general feature of egg activation.

Thermal Imaging Helps Detect Breast Cancer

A medical thermal scanner was designed and built under a grant from the National Cancer Institute to provide a real-time thermal imaging device for early detection of breast cancer. The scanner uses high-performance TV-compatible Forward Looking Infrared (FLIR) technology.

The scanner produces infrared imagery which may be either digitized, for computer processing, or stored on video tape for subsequent playback. The video imagery is radiometrically calibrated to provide an absolute temperature readout. The device will detect and indicate minute temperature differences (as low as 0.1°C) which are necessary to identify the presence of breast assymmetry, the primary indicator of breast cancer as displayed in a thermogram.

Early Detection of Small Lung Tumors

The University of Southern California Comprehensive Cancer Center in Los Angeles, California, has developed techniques for locating small lung tumors utilizing equipment containing an image intensifier tube.

The new method, fluorescence bronchoscopy, utilizing a bronchoscope (Figure 10), involves injecting the patient's bloodstream with a chemical that accumulates at the tumor and appears red under ultraviolet light.

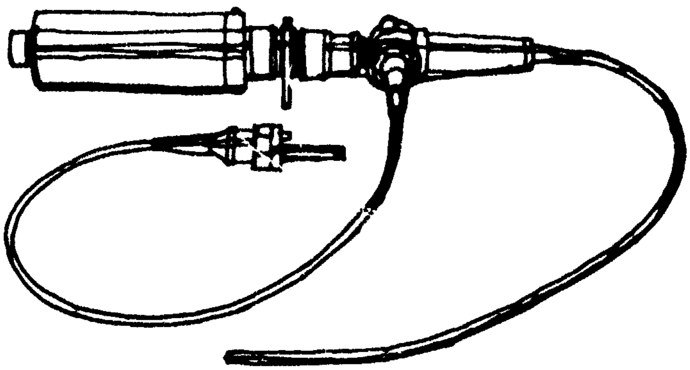


Figure 10. Bronchoscope with Image Intensifier

The ultraviolet light, provided by a LASER, is channeled via a flexible tube that is passed through the lung to inspect the bronchi. A coherent bundle returns an image to a lense and filter which provides a dim image input to the image intensifier tube. The amplified image output of the tube is viewed by the physician through an eyepiece.

Utilizing this equipment on a patient, who had smoked over two packs of cigarettes a day for 20 years and whose sputum displayed abnormal cells, showed an area of relatively bright flourescence in the right upper lobe of the patient's lung. On the basis of two separate studies, this lobe was removed and a tumor, smaller than a pin head, was found.

ENVIRONMENT AND SPACE

Night Vision Aids Forest-Fire Fighters

As a result of a special appropriation by Congress to fund the Forest Service for investigating techniques to avoid wildland fire threats, several projects were initiated including one to evaluate helicopter night operations.

The Forest Service, the Los Angeles Fire Department, and others including NV&EOL joined in this investigation. The NV&EOL provided image intensification and thermal imaging devices installed on a UH-1M helicopter for this investigation.

After initial training sessions on night vision equipment principles and operation, a set of missions was planned and accomplished to evaluate the value of night vision with respect to fire detection and fire fighting tasks. The results were very encouraging.

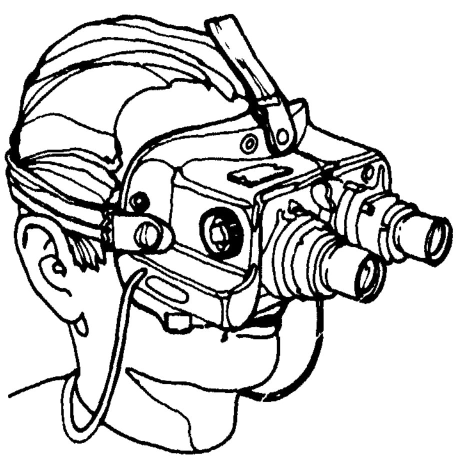


Figure 11. Night Vision Goggles

The first experience with night vision and an actual forest fire was in early 1974—the 100-acre Devil's Canyon Fire in the Angeles National Forest. The night vision helicopter crew flew near the fire. This mission marked the first viewing of a forest fire through Night Vision Goggles (Figure 11). The crew found that, not only could they see the entire periphery of the fire with the goggles, but that they could identify hot spots that could not even be seen with the unaided eye.

On the Soboba fire in the San Bernardino National Forest, a helicopter crew, equipped with Night Vision viewers was able to accurately deliver and dump at night, a total of 16,000 gallons of water on the fire during a four-and-a-half-hour period. This required refills of the helicopter's 330 gallon tank and numerous flights during this period.

Several important discoveries were made during this operation: the Night Vision Goggles could be used for extended periods without undue fatigue; the light from a fire is an excellent supplement to ambient light, although the pilot must avoid direct viewing of the flames, and water appears to have superior fire suppressing qualities at night because of reduced wind and temperature.

During the following year the Los Angeles Fire Department helicopter crews flew over 40 hours of night missions. In 1976 operations were expanded into Southern California by utilizing a twin-engine, night-operations equipped, Bell 212 helicopter based on the Los Padres National Forest.

As a result of using a Forward Looking Infrared System (FLIR) loaned by the NV&EOL, the Forest Service determined that the FLIR is an effective aid in forest fighting because of its ability to enable firefighters to see through the smoke and haze generated by fires. Additionally, a hand-held thermal (Infrared) Viewer was loaned to the Pennsylvania State Forestry Department for tests in detecting forest and grass fires in their early stages and for detecting active fires through smoke during firefighting operations.

It should be noted that the Canadian Forestry Research Center has reported that low-intensity holdover fires, undetectable by standard means, result in many damaging forest fires. They also reported that by using an infrared device, similar to the FLIR, 15 holdover fires were detected for every one found through conventional methods. The holdover fires were detected using this device on helicopters flying at 100 meters over areas susceptible to holdover fires.

Oil Spill Detection for the Coast Guard

The NV&EOL worked with the United States Coast Guard, Marine Technology Division, Buzzard Point, Washington, D. C., for the purpose of testing the value of the Forward Looking Infrared (FLIR) with respect to aerial oil-spill detection.

An NV&EOL FLIR was test flown over a controlled oil spill of Number 2 home heating oil to determine the feasibility of utilizing the FLIR to detect such oil spills. Test data was taken in the mid-morning, at noon, mid-afternoon, and at three hours after sunset. In all cases the spill was detected by a trained operator using the FLIR.

In respect to infrared, the heating oil spill appeared colder than the surrounding water or land. Since the FLIR is a thermal or heat sensing device, cold areas appear darker on the FLIR screen, therefore, the unpolluted water appears relatively bright on the screen with the oil spill appearing as dark areas.

The thicker the oil film on the water surface, the darker the image will appear on the screen. A trained FLIR operator can determine the shape of a spill, and roughly determine its thickness. During these tests, the controlled spills of Number 2 heating oil up to 150 microns in thickness were detectable from .5 kilometers to 2 kilometers.

The conclusion drawn from these tests was that the FLIR is an effective tool for use in oil spill detection during clean-up operations.

Subsequently NV&EOL provided technical information and assisted in preparation of specifications used by the Coast Guard for infrared system procurement.

Cloud Height and Range Measurements

NV&EOL developed a portable laser device for the meterological community which is capable of measuring vital range and height of clouds. The device is called a VISIOCEILOMETER. The measurements are accomplished by firing a single low-energy laser pulse at the source and analyzing the atmosphere backscatter (atmospheric) return.

The Visioceilometer, a modified Handheld Laser Range Finder, may be used by weather stations and airports to obtain meterological data. It can also be used from aircraft and ships to provide pertinent weather data.

The Visioceilometer has another potential use for effective pollution monitoring and control. For example, factories could use the device to monitor and control the emission of gas mixtures during their industrial activities.

Heat Pollution Evaluation

The Thermoviewer has been used successfully in aircraft to detect thermal pollution, such as power-plant effluent patterns, in bodies of water and in geophysical surveys involved in the study of conditions affecting the surface temperature of the earth.

Atomic Power and Animal Mortalities

Bowling Green State University, Environmental Studies Center, Bowling Green, Ohio, has used a starlight scope for evaluating bird mortality patterns associated with the cooling tower and other structures at the Davis-Besse Atomic Power Plant. Nocturnal observations of predators such as raccoons and skunks have been made with a starlight scope to determine the specific movement patterns of these animals and to determine whether the bird mortalities are the result of power plant or animal actions.

Telescope Aiming for Skylab II

During the Skylab II Mission, a problem was discovered with the operation of a very important ultraviolet telescope being used in the study of a solar phenomena. The Night Vision Pocketscope provided the solution by allowing the Astronauts to accurately aim the telescope from the cathode ray tube display inside the orbiting Skylab. Skylab II astronauts used a pocketscope with a slow-response phosphor to view the cathode ray tube display of the solar telescope. Since the image of the sun appeared for only a fraction of a second, the lag in the special phosphor screen of the pocketscope enabled them to properly aim the telescope and obtain the necessary data.

SAFETY

A Mining Safety Aid

The United States Bureau of Mines desired a means for reducing the high death rate (200 deaths a year) resulting from the collapse of loose rock in U.S. mineral mines. NV&EOL personnel worked closely with Bureau personnel to establish the feasibility of utilizing the Army's hand-held thermal imager in the detection of the loose and dangerous rock in mines, and secondly to develop a special explosion-proof model.

An explosion-proof thermoviewer has since been developed. It is about the size and weight of a pair of binoculars and can "see" in absolute darkness.

Figure 12. Commercial Thermal Viewer

The thermoviewer creates images by sensing minute temperature differences between the viewed object and its background. Solid rock will reach an equilibrium temperature that depends upon the temperature and flow of the air, the thermal conductivity of the rock, and its ambient temperature. However, if a loose rock exists among this solid rock, there will be a thermal air barrier between the loose and the solid rock. The loose rock will be affected more than the solid rock by air temperature changes and there will be a temperature difference. Since the loose rock has a slightly different temperature than solid rock, the thermoviewer can detect and display that difference enabling potentially hazardous rock faults behind apparently solid mine walls to be detected.

The U.S. Bureau of Mines now considers the thermoviewer an indispensable safety device and has procured thermoviewers for use by its inspectors (Figure 12).

Aircraft-Bird Collision Studies

The Department of Zoology, College of Sciences, Clemson University, in conjunction with the U.S. Air Force has been investigating applications in avoidance of bird-aircraft collisions for improvement of flight safety. The loan of a starlight scope assisted this effort in the detection of birds aloft at night.

The Starlight Scope was provided to assist in detecting concentrations of roosting birds and in observing flocks of overhead migrating birds at night. The scope permitted the tracking of the birds without the disrupting influence of a visible light beam. This enabled the identification of general types of birds flying overhead at night with far greater accuracy than possible in the past.

The scope enabled direct visual identification of birds causing radar echoes. This information was required to complement radar data on bird migration. Although radar detects even some of the smallest birds aloft, very little has been known about the specific types of echoes produced by different types of birds.

As a direct result of the above radar studies complemented by the Starlight Scope, data obtained has been invaluable and has been a major factor in the reducrion of loss of life caused by aircraft-bird accidents.

Thermal Imaging for our Airlines

NV&EOL representatives assisted the Federal Aeronautics Administration (FAA) in studying systems to improve airline visibility during fog conditions. This included providing consulation to the FAA with respect to determining the most effective technology for solving the fog problem. NV&EOL representatives planned a test at the Fog Chamber at the University of California, Berkeley, monitored the performance of the test, and prepared reports for the FAA. Subsequently, NV&EOL representatives assisted in the planning of a program for active infrared testing with respect to aircraft and airports during poor visibility landings. Test results were encouraging with respect to this technology as an aid for use during poor landing visibility.

Aircraft Troubleshooting Assistance

In several cases, pilots executing night landings in F-15 aircraft, at Luke Air Base, Phoenix, Arizona, had erroneous instrument-panel indications that their landing gears had lowered and properly positioned for landing. Several of these erroneous indications resulted in serious accidents during landings. In order to continue these night exercises while troubleshooters diagnosed the problem, NV&EOL was requested to assist by observing the night landing aircraft with thermal and image intensification devices. As a result of NV&EOL's assistance, no further accidents occurred during the diagnosis period (Figure 13).

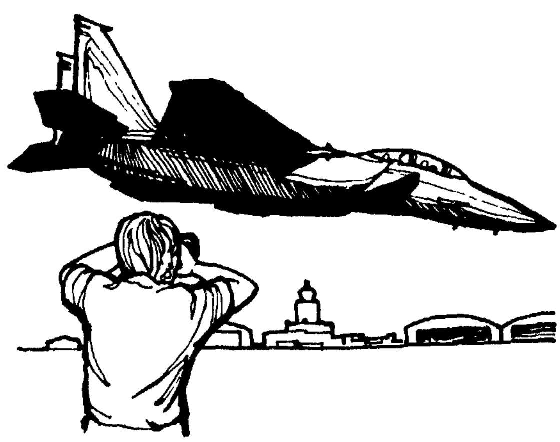


Figure 13. Trouble-Shooting Assistance with Night Vision

CONSTRUCTION, FACILITIES MANAGEMENT, AND SURVEYING

Housing Heat Loss Evaluation

The handheld thermal viewer detects temperature differences and therefore has been found to be a valuable tool in detecting the location of heat loss from homes and buildings (see Appendix 1).

The handheld thermal viewer has been used to detect energy leakage for construction analysis of low-cost housing units in order to upgrade construction requirements in the city of Philadelphia, Pennsylvania.

The Montana Energy Research and Development Institute, Incorporated, required the use of the handheld thermal viewer to evaluate the winterization of low-income housing.

Detecting Defective Insulation

The U.S. Army Facilities Engineering Support Agency, Research and Technology Division, Ft. Belvoir, Virginia, has found that the handheld thermal viewer is effective in detecting moisture in insulation installed under flat-roofs. The location of unwanted moisture caused by roof leaks is easily identified with these infrared devices.

During the day, the sun's heat raises the building's roof and interior temperature; and during the night the heat passes from the interior of the building back to the outside air. Since wet insulation conducts heat faster than dry insulation, infrared devices can usually detect the difference between the roof temperature over the wet insulation and the roof temperature over the dry insulation.

Aerial infrared photographic scanners and handheld thermal viewers have been effective in selecting potential damp insulation problem candidates for subsequent evaluation. However, results are not infallable. For example, difficulty may be encountered in determining whether the water is on the surface of the roof or in the insulation. Varying thickness of roofing, the presence of heated pipes or ducts, and the effects of air-conditioning may also cause misleading indications.

Facility Inspections With Infrared Viewers

The U.S. Army Facilities Engineering Support Agency has found that the handheld thermal viewer is useful in facility inspections.

The handheld thermal viewer has been found to be effective in the periodic inspection of electronic transmission and distribution lines and associated equipment. Loose connections, overloaded transformers, defective high-voltage switchgear, and other similar problems produce heat which is readily detected with infrared viewing devices. Further, the entire inspection can normally be accomplished on live electrical power systems without the adverse mechanical effects associated with the periodic tightening of all connections.

Infrared viewers have also been successfully used to evaluate power-plant hot water effluents, to locate underground steam and hot-water line leaks, and to inspect steam traps. For example, through the use of an infrared viewer, a laundry with 200 steam traps can be evaluated in a 3-4 hour walk-through survey – a fraction of the time previously required.

The cost effectiveness of both military and commercial infrared detection equipment is continuously undergoing evaluation. The conclusions are, that these devices have great potential and value as diagnostic aids in areas where heat differentials are a key factor.

Detection of Oil Leaks in the Alaskan Pipeline

An NV&EOL representative provided a major United States Oil Company with consultative services with respect to utilizing thermal technology for detection of oil leaks in the Alaskan pipeline. Because of the urgency of the requirements, a commerical thermal imaging unit, which had been developed as a result of technology transfer, was suggested for immediate use.

Surveying Forests with Night Vision

The Forest Service has experimented in utilizing a transit-mounted Night Vision scope for direct viewing of vertical laser beams or "range-poles" at considerable distances. The laser range-pole is the surveyor's latest method for accurate sighting from several miles away. Previously an all electronic system, with sophisticated gating requirements, was used to detect short low-power laser pulses. By using night vision scopes, with low-energy laser range poles, at dusk or night, the need for this higher-cost equipment is eliminated.

The Forest Service and, more recently, the Bureau of Land Management have been using an instrument which is a direct spinoff of the Army-developed Laser Rangefinder. This instrument is being used to survey boundries which are difficult to survey using conventional techniques. These new instruments are reliable, more accurate, and have reduced survey time considerably.

COMMUNITY SERVICE

Air Rescue with the Night Vision Goggles

After losing radar contact with a small private plane, the Air Traffic Controllers at Dulles International Airport, Fairfax, Virginia, contacted Davison U.S. Army Airfield, Ft. Belvoir, Virginia, for Army rescue assistance. The Davison tower, being aware that two night-vision equipped helicopters from NV&EOL had just taken off for the purpose of testing Night Vision Goggles, contacted them and instructed them to make contact with the Dulles traffic controllers by radio.

Dulles Air Traffic Controllers vectored the two night vision helicopters to the location where the private plane had last been seen on radar. Using their Night Vision Goggles, the NV&EOL crews located the downed plane within approximately 15 minutes after its crash.

One of the helicopters hovered over the area illuminating the site with a searchlight while the other helicopter landed in the very rough terrain. The crew removed the two injured private-plane victims, and transported them to Dulles where an ambulance carried them to a Loudoun County hospital. The hovering helicopter remained over the crash site until Virginia State Police arrived to secure the area.

Disaster Assistance with Night Vision Searchlights

Following the collapse of a high-rise apartment building under construction in Northern Virginia, the NV&EOL sent a truck-mounted 30 kilowatt searchlight manned by NV&EOL personnel to provide illumination during search operations for victims of the collapse. The searchlight and crew provided nighttime illumination for a period of almost two weeks. Following the operation, county officials stated that without this aid, their night searches would have been impossible.

On another occasion, a tornado severely damaged a shopping center in Northern Virginia County police officials were concerned over the possibility of looters entering the tornado-damaged businesses. At the request of county officials, the NV&EOL sent searchlights manned with NV&EOL personnel to illuminate the damaged shopping center throughout the night and until security could be restored.

Illuminators for the Coast Guard

The NV&EOL developed, for the U.S. Coast Guard, Marine Technology Division, a design specification and test plan for an HH-3F helicopter-mounted, wide-angle illuminator for Coast Guard search operations.

This task involved NV&EOL personnel in performing a searchlight analysis study using a computer search model. The NV&EOL personnel developed definition and design criteria, accomplished a survey of existing light sources, and determined modifications required for existing searchlights. Based on these efforts and the resulting specification, the U.S. Coast Guard procured searchlights for helicopter rescue missions. These searchlights are in use today guarding our coast and waterways.

On another occasion, the U.S. Coast Guard borrowed a one-kilowatt xenon searchlight to test its value in various patrol functions. As a result of these tests, NV&EOL was given the task of providing a precision searchlight mount for use on the U.S. Coast Guard's medium-range endurance cutters.

Image Intensifier–Big Hit at Science Fair

The NV&EOL received an unusual request from a Warren Central High School student in Kentucky. ". . . I am interested in doing some research comparing the behavior of various forms of microscopic life at night to their behavior during the day. In particular, I wish to study the metabolic and reproductive activities of algae, bacteria, and microscopic cave animals. To aid this, I propose to build a microscope utilizing an . . . image intensifier . . . any help you can offer would be greatly appreciated . . ."

In response, an NV&EOL scientist sent the student a letter suggesting that he build a simulator to test his ideas and that a tube would be loaned once a feasible approach had been determined. The student followed the suggestions and was eventually loaned an image intensifier tube, eyepiece, and associated technical data.

The student designed and built a "Low Light Image Intensification Microscope" for the study of marine micro-organisms behavior under nighttime conditions and in March 1979, entered it in the Southern Kentucky Regional Science Fair at Western Kentucky University, Bowling Green, Kentucky.

He took 1st place overall–1st in the physics category, the NASA Award, the American Society for Microbiology Award, the U.S. Army Award, and the U.S. Navy Award. He was then eligible for the International Science and Engineering Fair held in May 1979 at San Antonio, Texas where he finished in 4th place. He has since applied for a patent on his design.

Thermal Viewer and the Heat Energy Loss Project

In 1980, the Physics Classes at Warren Central High School in Bowling Green, Kentucky, received a $336 grant, from the American Association of Physcis Teachers, to study the school's use of heat energy. The study was called "H.E.L.P." (Heat Energy Loss Project). The study included: daily monitoring of each room for temperature and relative humidity; surveying each room to determine radiator locations and controls, room sizes and window areas; and subsequently analyzing this data.

As part of the study, the students requested from NV&EOL a one-day loan of a handheld thermal viewer in order that an infrared analysis could be made of the school's radiator system. An NV&EOL engineer visited the school, on his own time and at his own expense, to supervise the students as they viewed each of the 44 radiators within the school. The students discovered that 34 of these radiators, or 77%, were partially or completely blocked, greatly reducing their efficiency. The study culminated in a student-prepared report which included study data, analysis, and conclusions. As a result, the project won the American Association of Physics Teachers "Innovative Teaching Grant Award."

LAW ENFORCEMENT

Supporting Our City Police

NV&EOL has worked closely with several city police departments in an effort to support them as requested in areas of night vision technology.

NV&EOL has provided the *Washington, D.C. Police Department* with information, design guidance, demonstrations, and equipment. Equipment including image intensifiers, near-infrared equipment, and searchlights has been loaned, along with information and advice about their operation and use. The Laboratory has demonstrated the Forward Looking Infrared System (FLIR) to the D.C. Police Chief, during a flight over the city of Washington, to show the capabilities of this device.

Laboratory representatives have also provided design guidance to the D.C. Police in respect to the development of a TV system for use in both high-crime areas of the city and for use with the D.C. Police Helicopter.

The laboratory has worked with other city police departments. They loaned a small starlight scope and furnished information on other night vision systems to the *Los Angeles Police Department* and they demonstrated various night-vision devices for the *New York City Police Department* and the *New York Transit Authority Police.*

NV&EOL loaned a small starlight scope to the *Montgomery County (Maryland) Police Department* for their use in determining its feasibility in county law enforcement. A 30 kilowatt searchlight was also loaned to the *Miami Police Department,* during the Republican Nominating Convention, to provide illumination in case of public disturbances.

Narcotics Traffic Control

NV&EOL has given considerable assistance to the Treasury Department in respect to the use of night vision equipment in narcotics raids on the Arizona-Mexico border. This assistance included training Treasury Agents in the use of starlight scopes. As a result of these raids, Treasury Agents seized $19 million worth of narcotics including 24 tons of marijuana.

The Sanibel Island, Florida, Police Department applied for and received a grant under the Law Enforcement Assistance Act to purchase a pair of night vision goggles to assist in their Narcotics Traffic Control Program. Sanibel's unique position, just off the Florida coast in the Gulf of Mexico, had provided drug smugglers numerous well-hidden docking points for the transfer of drugs; however, the Sanibel Police, equipped with night vision goggles, doubled their coastline surveillance through night operations. This resulted in the apprehension of numerous drug smugglers and the direct reduction of drug transfer to the United States via Sanibel Island.

Border Surveillance at Night

The U.S. Border Patrol has used the TOW missile night sight to observe illegal alien movements. The TOW missile night sight, which can image differences in temperatures between persons and naturally occurring backgrounds, was designed to identify armored targets at night for the TOW missile launcher.

This night sight, which can detect men at very long ranges at zero illumination from the moon and stars, is being used to apprehend illegal aliens crossing the Mexican-U.S. International Border. Previously, several agents were required to track aliens in total darkness; but now, one can detect aliens at long distances and direct the apprehending agents to the exact location. Therefore, many miles of border can now be observed with a relatively small number of observers, thus freeing more agents for the apprehension mission.

The Border Patrol has also studied other night vision devices, especially airborne and ground-based image intensifier systems, which could make the agents more effective at night. One such device, the Night Observation Device – Long Range (NODLR) is now being successfully used by the Border Patrol at Calexico, California (Figure 14).

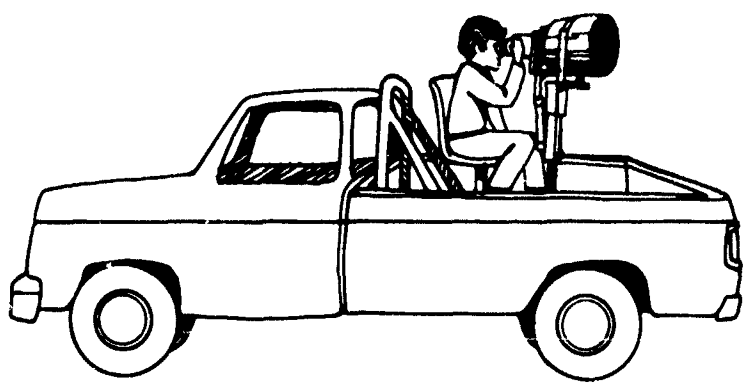


Figure 14. Truck-Mounted Long-Range Night Observation Device

Handheld Thermal Viewers for the U.K. Police

The Optics Group of the Police Scientific Development Branch in the United Kingdom evaluated thermal-imaging equipment for police applications. They determined that the most successful equipment evaluated was the NV&EOL developed Handheld Thermal Viewer which "combines small size, ease of operation and good optical performance." (Figure 15)

The Police Scientific Development Branch has an interest in thermal viewers for use in: searching for lost or missing persons, searches for fugitives, surveillance of grounds of large buildings for intruders, and detection of small boats coming ashore at night.

They determined that the Handheld Thermal Viewer could identify a man at up to 200 meters, detect him at over 500 meters in the open (with fairly uniform background), and at 60 to 80 meters in the woods. They could identify vehicles at 300 to 400 meters and detect them at up to 1000 meters if they were moving. It was also found that, with a helicopter flying at heights between 100 and 400 meters over various terrains, it was possible to detect most of the people and vehicles in an area of one square mile within a 25-minute period.

As a result of the tests of the Handheld Thermal Viewer and other themal imagers, a specification was written and competitively bid by several United Kingdom companies and a contract was awarded for the design and production of a lightweight thermal viewer.

Figure 15. Handheld Thermal Viewer

Night Vision Helps Catch Sex Offender

For three years a sheriff's office in Arizona had been unsuccessful in apprehending a lone sex offender. The masked offender would approach cars parked in dark, lover's lane areas, order the occupants out at gunpoint, tie up the male occupant, and sexually assault the female companion.

After three unsuccessful years of investigation and 19 reported rapes, a decoy surveillance was conducted using a borrowed pair of Night Vision Goggles. A female and male deputy acted as the decoy couple, and a third officer, equipped with the Night Vision Goggles, acted as the cover officer.

In the words of the Maricopa County Sheriff, "for a period of 33 nights, we conducted a surveillance . . . (before) we made contact with the suspect . . The officer shouted warnings to the suspect to stop, and identified himself as a law enforcement officer. The suspect (who was masked and armed) refused to comply with the command and headed for the occupants of the vehicle . . ."

"In fear the suspect might harm the decoy officers or take them hostage, the cover officer fired one shot from his weapon. Due to his outstanding night vision, the officer was able to direct his fire away from his fellow officers and low enough to strike the suspect in the leg in a non-lethal area. The suspect was taken into custody without further difficulty."

Other Uses of Night Vision Equipment in Law Enforcement

Other uses of night vision equipment provided by NV&EOL for law enforcement purposes have included:

- The Justice Department was assisted in their evidence collection. A starlight scope was loaned to assist the photographing, via 16mm motion pictures, of railroad locomotives and cars during the day and night.

- The City of Huntington Beach, California, in their quest to control nine miles of beaches, borrowed Night Vision Goggles for use in their helicopter surveillance program.

- The Ft. Belvoir, Virginia, Military Police borrowed starlight scopes and other special purpose systems in their base security program.

- The Ohio Department of Natural Resources, Columbus, Ohio, borrowed a Medium Range Night Observation Device to investigate its usefulness to wildlife law enforcement.

- During the latter part of 1975, a pair of night vision goggles was loaned to the Plumas National Forest for use in detecting nocturnal Christmas tree poachers. A deterrent effect resulted from the awareness, by would-be poachers, that Federal Forest Officers were using Night Vision devices.

- The Potomac River Fisheries Commission (a joint Virginia and Maryland Commission) successfully used a handheld infrared searchlight and a pair of night vision goggles to assist in the apprehension of oyster poachers who had previously been able to escape in their high-powered boats.

- Rangers of the National Park Service have borrowed the starlight scope in an attempt to prevent alligator poaching in the Everglades National Park.

- The Ohio Fish and Wildlife Service borrowed a scope in order to combat fish poaching in the Great Lakes.

MAMMAL STUDIES

Observing Chimpanzees, Baboons, and Gorillas at Night in Africa

Image intensifier devices have been loaned, through the National Geographic Societ_, to Dr. Jane Goodall, a British researcher, to assist in the study of chimpanzees and baboons in Africa and to Diane Fossey to assist in her study of the African Mountain Gorilla.

Dr. Goodall started her research of chimpanzees in Africa in 1960 and became director of the Gombe-Stream Research Centre on the eastern shore of Lake Tanganyika in Tanzania. Dr. Goodall and Centre personnel used the starscope in 1974 in their research. Following is the major portion of a letter written about the Centre's use of this starscope.

> "This night viewing instrument has been very useful to the research team at the Gombe Stream Research Centre over the past years. Its uses have been twofold.
>
> "Firstly, it was taken into the field by students working on chimpanzee mother-infant behavior. A great deal of information has been collected on this subject, but almost all in daylight hours. With the help of the Starscope a number of watches were kept during the night on mothers and infants in their nests. Some interesting observations were made – it was ascertained that infants do suckle at night, for instance. But it was found that greater magnification was necessary for really detailed observations of chimpanzees up in their tree nests.
>
> "Secondly, the starscope was used by members of the team studying baboon behaviour. These observations taught us more about the movement, in the trees, of different members of the baboon troop at night... The starscope was especially helpful when a team of students was taking it in turns to watch a pregnant female for 24 hours at a stretch over several days. The delivery eventually took place, up in a tree, on a very dark night and some details were observed through the starscope..."

Selectively Exterminating Vampire Bats

The Starlight Scope has been used in research on vampire bats, a blood-sucking species that prey on cattle and carry rabies. Although a small minority of the total bat population, the vampire poses an especially serious problem in South America where it causes cattle loss valued at some $350 million annually.

Researchers have employed the Starlight Scope to identify the vampire bat before selectively exterminating it without harm to the entire bat population, and to study bat feeding habits in an effort to control those responsible for destroying large quantities of fruit in the tropics (Figure 16).

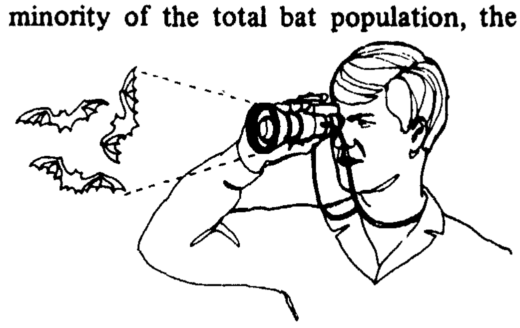


Figure 16. Starlight Scope

Other Mammal Studies

- The University of Minnesota, Department of Entomology, Fisheries and Wildlife, St. Paul, Minnesota, used a starlight scope to determine movements in the winter range and spring migration of the white tail deer. Studies also include, as part of the effort, documentation of the food and predation of the timber wolf.

- The Pennsylvania University has studied the behavior of deer with night vision devices in order to eliminate the serious highway hazard which they present at night.

- Beaver College, Glenside, Pennsylvania, has used a starlight scope in their research to observe rats under very low levels of illumination to preclude use of visual cues to guide or influence their behavior.

- The University of Vermont, Department of Zoology, Burlington, Vermont, studied a species of rodent, called the Hartian Hutia, with a starlight scope.

- The National Zoological Park, Smithsonian Institution, has used a handheld infrared viewer and visible searchlight to observe animals at night in open paddocks at their breeding facility.

BIRDS, SEA LIFE, AND INSECTS

Observations of the Feeding Habits of Birds

The unusual expanded bill of the boat-billed heron (cocklearius cocklearius) has for years been assumed to be associated with some special feeding techniques but, because of the bird's nocturnal feeding habits, this assumption could not be verified.

In an effort to shed further light on this subject, personnel of the College of the Atlantic, Bar Harbor, Maine, used one of NV&EOL's Starlite Scopes to observe the nocturnal feeding of the boat-billed heron in a Pacific Guatemala marsh.

On 16 evenings, twenty-three feeding boat-billed herons were observed, for periods of from 25 to 95 minutes each, through the night vision sight. When necessary, available light was supplemented with a red light, made by affixing 16 layers of red cellophane to a sportsman's headlight. The observations were made from a blind constructed of camouflage colored mosquito netting.

Boat-billed herons, which came as close as 15 meters, were observed from the blind with the night vision sight. The birds arrived for their feeding about 25 minutes after sunset and were observed until two or three hours after dark.

Despite the predictions that the boat-billed herons must have special feeding habits because of their unique bills, the observations indicated that they fed by common heron techniques and take much the same prey.

Protecting Alligators In Florida

The Southwest Florida Regional Alligator Association, Sanibel Island, Florida, was formed because the Island's citizens were concerned about the declining alligator population. Their realization of the plight of these endangered species concerned these naturalists who believe that these creatures must be protected and their young saved from predators. The Association requested a Starlight Scope from the NV&EOL to observe the nesting habits of the female alligators. The request was granted and the Association went to work with its project.

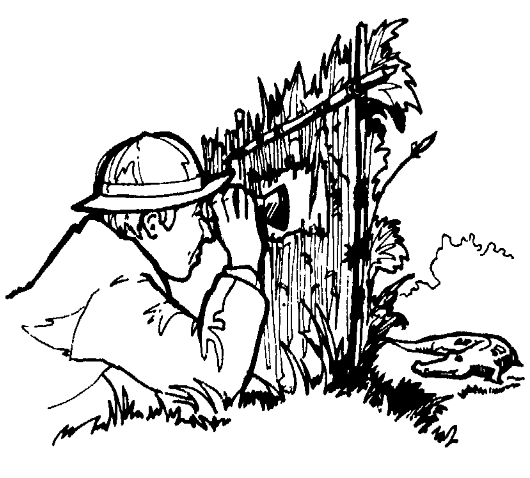


Figure 17. Wildlife Observations with a Starlight Scope

The project consisted of a team of 22 volunteers who watched selected alligator nests on a 24-hour basis when it came time for the eggs to hatch. A blind was constructed close to one of the alligator nests, and the vigil commenced with each volunteer taking a three-hour shift. The Starlight Scope was used during the 3:00 AM to 6:00 AM shifts to observe the nest during that period (Figure 17).

Based on their observations, the Association presented their data and made recommendations to the Florida State Game Authority.

Night Vision Device Helps Find Fish

Schools of fish often cause the emission of light (bioluminescence) by agitating dinoflagellates plankton. Normally commercial fisheries utilize spotter aircraft to search and find schools of fish. But, as a result of advances in night vision technology and the presence of the bioluminescence characteristic of schools of fish, a special device to spot fish at night from the air was developed and tested.

This special device was designed and tested by a private contractor for a commercial fishing organization. The design consisted of a f/1.2, 160mm catadioptic lense which had originally been developed for the U.S. Army's Crew Served Weapon Sight, an early version 40mm image intensifier tube, and a biocular eyepiece.

Observing Crop-Destroying Night-Flying Insects

Night Vision Goggles developed by the NV&EOL have been used by Department of Agriculture researchers in studying crop-destroying insects, specifically a large variety of night-flying moths (Lepidoptera).

Since insects often display altered behavior at night when exposed to artificial light sources, knowledge of their night behavior is limited. However, with the aid of the Night Vision Goggles, this knowledge has been rapidly expanding.

Observations of these insects with the Night Vision Goggles were conducted in Norman, Oklahoma; Pelham, Georgia; Brownsville, Texas; and Phoenix, Arizona. Data was collected about insect movement and the effect of Pheromone Plumes on these movements. Pheromone is a female insect emission which attracts males during mating. The Night Vision Goggles were also used to evaluate the efficiency of several trap designs, at night, utilizing virgin female insects and synthetic pheromone as an attraction.

Other Bird and Sea Life Studies

Other uses of night vision equipment provided by NV&EOL for bird and sea life studies included:

- The United States Department of the Interior, Fish and Wildlife Service, borrowed a starlight scope for use at their Point Reyes Bird Observatory in the Farallon National Wildlife Refuge, California. This scope was used to determine census, areas frequented and the activities of nocturnal and diurnal seabirds and to study the northern elephant seal cow-pup relationships. The data gathered " . . . were unique in the science of animal behavior."

- The University of Minnesota used a starlight scope in the study of the North American Woodcock, a short legged, long-billed bird with a brownish plumage.

- The University of Maryland (Department of Zoology), College Park, Maryland, used Night Vision Goggles to continuously monitor large and small sitting whales for identification and for whale population studies.

- The University of Arizona, Tucson, Arizona, borrowed a Night Observation Device to observe sea turtle mating and nesting activities in the proximity of breeding beaches for the purpose of answering important biological questions concerning the behavior and population dynamics of this endangered group of animals.

- A Professor of Biology at Cerritos College required the use of an image intensifier in observing the luminous behavior of the Porichthys Natatus whose courtship involves bioluminescence. The device was required to facilitate visualization of the luminous display and postural details of the remarkable courtship pattern of this fish.

- Researchers at the Smithsonian Institution in Washington, D.C., borrowed a handheld infrared xenon light source and a pair of night vision goggles to assist in their study of bat mating habits.

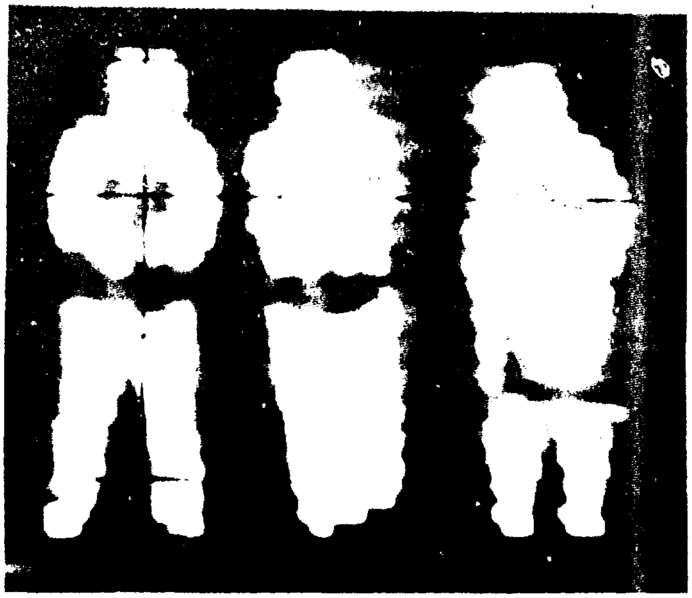
IV POSTSCRIPT

The NV&EOL has been fortunate to have been at the forefront of the exciting new technologies of night vision and electro optics. Within the past decade, the NV&EOL has seen many of the results of its research and development efforts being applied to non-military use. In many cases, scientists, engineers, and others beyond the NV&EOL structure have been quick to grasp and mold these technologies into new and exciting spinoffs useful in such areas as: health and medicine, environment, space, safety, construction, facilities management, surveying, community service, law enforcement, and biological studies.

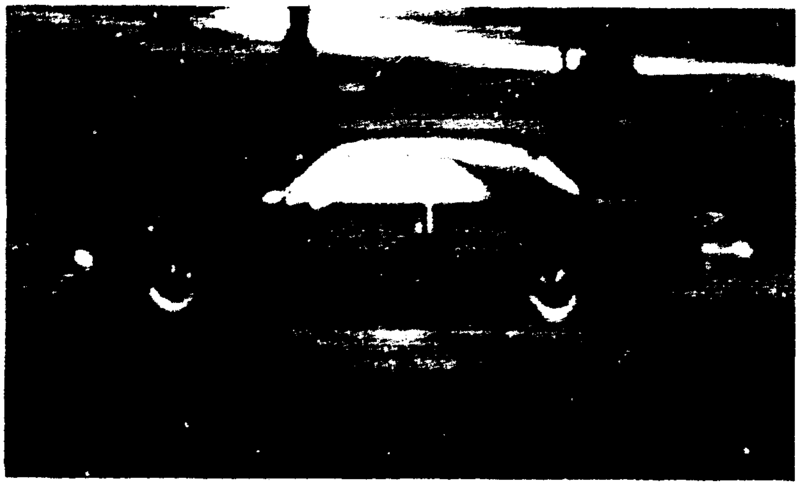
The NV&EOL supports this trend – even backs it by providing direct assistance and by participating in national and regional: workshops, briefings, lectures, and conferences. NV&EOL representatives have participated in conferences with such themes as *Utilizing our Technology*, the *Stevenson-Wydler Technology Innovation Act of 1980*, the *National Innovation Network*, and the *Mid-Atlantic Regional Technology Exchange Conference.* In the latter case NV&EOL provided displays and hands-on demonstrations.

NV&EOL, as a member of the Federal Laboratory Consortium for Technology Transfer, has pledged to assist those individuals and organizations that desire to adapt its technology developments for peaceful applications. NV&EOL's first responsibility, however, is to develop night vision and electro-optic: infantry systems, armor systems, anti-armor systems, and aviation systems. Therefore, all of NV&EOL's other activities, including *technology transfer,* must at times be subordinated to its first and most critical mission – *national defense.*

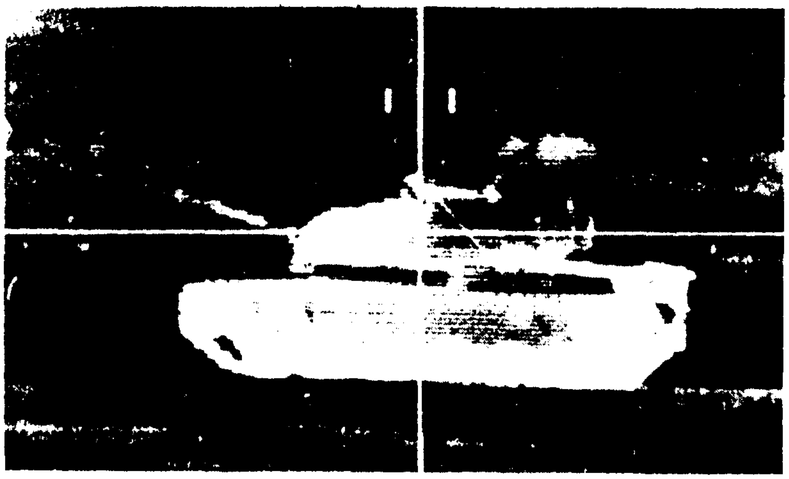
Night Scene – Image Intensifier



Night Scene – Infrared Viewer



Night Scene – Infrared Viewer



Night Scene – Infrared Viewer

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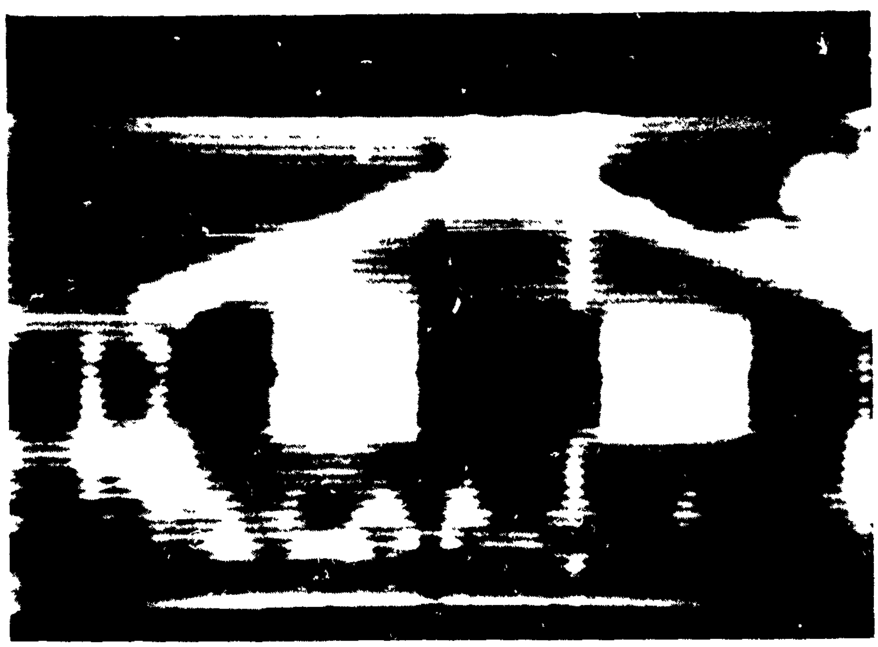
Daylight View of Home



Infrared View of Same Home Showing White Areas of Heat Loss

APPENDIX 2 – NIGHT PHOTOGRAPHY

General Considerations

Work at NV&EOL has centered primarily on two types of imaging devices – image intensifiers and far infrared (thermal imaging). The laboratory has been actively engaged in both 16mm motion picture and 35mm still photography work as it relates to these two technologies. Motion picture and still picture techniques found to be successful by the laboratory are described below. There are however, no hard and fast rules. The laboratory's experimentation with different films, brackets, cameras and other items has led to certain techniques. These techniques have evolved over several years of trial and error and have proved successful for the NV&EOL. However, these techniques should not be considered as the only ones that will yeild success. Don't expect to make award-winning exposures on your first night in the field because each different assignment will require trial and error on your part.

Still Photography With Night Vision Devices

The principal pieces of equipment required for night vision still photography are: an image intensifier (goggles, pocketscope, or starlight scope); a good single lens reflex camera; an exposure meter; a tripod; and a custom-built bracket to mate the camera and intensifier (Figure 2-1).

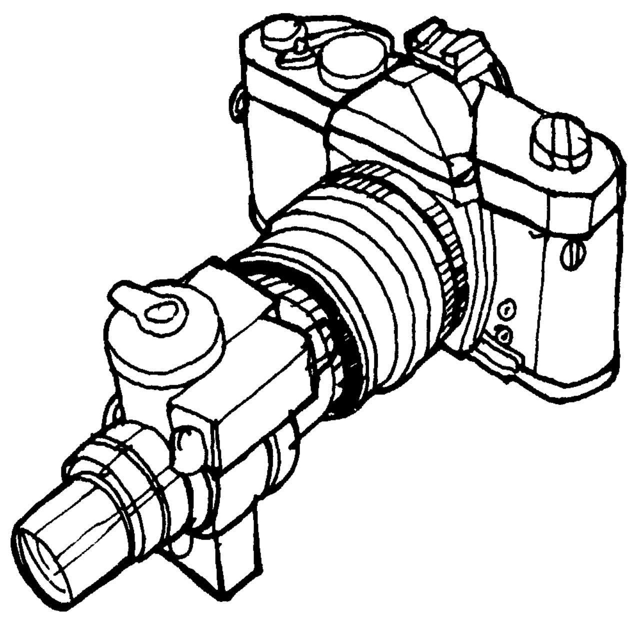


Figure 2-1. 35mm Camera Equipped with an Image Intensifier

The only piece of hardware listed above that requires explanation is the custom-built bracket. The purpose of the bracket is to maintain proper alignment between the camera and the intensifier eyepiece. One technique which has been used, is to make a small cardboard disc which is inserted into a standard filter holder and threaded onto the camera objective lens. This disc performs two functions: it eliminates entry of any stray light into the camera, and it simplifies camera-intensifier alignment with respect to the mounting bracket.

Relay lenses are available to mate certain cameras with image intensifiers but the use of such lenses can be avoided by fabricating adapters. The relay lens would theoretically yield a gain of three f stops. The problem you may encounter, however, is difficulty in locating such a lens at an affordable price.

The next step calls for diopter (eyepiece) adjustment on the image intensifier. The diopter adjustment should be set at zero. Devices like the starlight scope have calibrated diopters labeled from -3 to +3 diopters. The goggles do not; however, with the adjustment mechanism set at a 180^{o} angle to the system, it is calibrated at zero. The next step requires adjustment of the objective lens to infinity. If both of these items are in proper calibration, the image through the intensifier, viewed in the camera viewfinder, should be in focus. If not, adjustment of either the camera objective lens or the system diopter setting is required so that accurate focus may be achieved.

With respect to films, Kodak Tri-X ASA400 is considered a good choice. There are a number of faster black and white films available, but they tend to have a greater extended-red response which does not match the spectral output of the P-20 phosphor used on almost all image intensifiers available today. All military systems developed at NV&EOL utilize the P-20 phosphor screen in which the spectral efficiency exceeds $6X10^{-5}$ watts/nanometer per watt between 500 and 700 nanometers. Photographic films exhibiting efficiency either above or below these wavelengths are impractical in this application.

In making prints, strange as it may seem, the use of Kodak Ektracolor paper, exposed to a black and white negative through a magenta filter yields sharper photographs than those achievable using color negative films. The green tint of these prints looks surprisingly realistic. When making such prints, a clear sheet of unexposed and processed color negative film, which appears orange, must be placed on the black and white negative to serve as a color mask.

In applications where long time exposures cannot be used, such as in photographs of moving objects, it is necessary to double or triple the film speed through the use of special developing solutions. Most films that have been push processed exhibit higher contrast and increased graininess, but this is presently not avoidable. The Laboratory has used Kodak Plus-X film rated at ASA 125 push-processed to ASA 800 by using a Microdol solution diluted 1:3 with water at 22^{o}C for 20 minutes. Although this developer is not noted for push processing, it is effective in limiting excessive graininess. One of the Laboratory's techniques is to use Kodak Tri-X processed in Kodak D-76. Normal processing (8 minutes at 20^{o}C) yields an effective film speed of ASA 400. The effective speed can be doubled by processing the film 12 minutes at 20^{o}C, or even tripled to ASA 1200 by processing the film 10 minutes at 23.9^{o}C.

Another important factor to be considered is the camera aperature adjustment. Theoretically, nothing is gained by opening the aperature wider than the effective f number of the night vision device. In the case of the night vision goggles, this is f8; in the case of the small starlight scope, it is f5.6.

When photographing through an image intensifier, at light levels of half moon or higher, the camera's built-in exposure meter will probably suffice. Since most exposure times are long, the use of a tripod is recommended. Under lower light levels, it is impossible to predict exposure time requirements because of such variables as light level, tube brightness, target contrast, and atmospheric conditions. It is essential that trial exposures, or a series of exposures using different exposure times, are made. The use of a 4X5 view camera equipped with Polaroid type 52 film, rated as ASA 400 makes a good double check. Although not always practical in the field, it does give excellent indication of how close exposure estimates are.

Since most built-in exposure meters have very poor response at low light levels, the Laboratory uses a Spectra Combi 500 exposure meter to measure low light levels. This meter utilizes a cadmium sulphide light-sensitive material that enables the reading of light levels in fractions of a foot-candle.

A separate meter such as the Combi 500 is used as follows. First, with the camera removed from the night sight, visually line up the sight on the target. Remove the photosphere and any multiplying slides that may be inserted in the slide slot on the light meter, and then place the bare cell window of the meter in direct contact with the ocular of the night sight. Depress the low-light-level button on the side of the meter and allow for a few seconds for the needle to stabilize. Using the Slide-out Indicator as a reference point, determine the proper camera diaphram setting and shutter speed combination. Remember that a diaphram setting exceeding the effective f number of the night vision device is ineffective.

Motion Pictures With Night Vision Devices

Many of the procedures outlined above for still photography apply to motion picture work as well. Kodak number 7224-4-X negati 16mm film has been found to be most effective. Negative films are preferred over the reversal types because of the latitude obtainable. Poorly exposed film, 1 or 2 stops over or under, can be salvaged with negative film but not with reversal film.

A 16mm through-the-lens reflex viewing camera capability is a necessity for focusing and aligning the camera with the night vision equipment. A 16mm lens has been found most desirable, however, if more magnification is desired, a 25mm lens is acceptable but some vignetting will occur.

By using 4-X film with normal processing, at a light level of $5X10^{-4}$ and a phosphor reading (through the eyepiece) of 16 foot candles an exposure of 16 frames/sec can be obtained. This is equivalent to 1/30th of a second.

Since color film requires a relatively high light level, a minimum of a half moon is required. When shooting at f2 at 12-16 fps, Kodak Ektrachrome type EF (daylight film) yields good results.

Some Final Points

The success in night photography depends largely on experimentation. No one set of rules will apply to all of the countless situations that may be encountered. Since commercial products are usually not available to mount night vision devices to cameras, a good machinist can be indispensible. Clearly explain to him the problem you are trying to solve. You will find that he can contribute significantly with good ideas on bracket fabrication techniques.

A final hint; always carry a roll of masking tape into the field. It has saved countless feet of movie film and 35mm still film in a variety of different ways.

Regardless of the night photographic problem you face, plan ahead, adapt to your environment, and experiment with new techniques and you will ultimately meet with success. However, if after experimentation, you continue to encounter problems, you may want to contact one of the NV&EOL staff photographers for further information.

APPENDIX 3 – CASE STUDY

MEMORANDUM FOR: Federal Laboratory Consortium for Technology Transfer

SUBJECT: Transfer of Night Vision & Electro-Optics Laboratory Technology into Industry

ITEM TRANSFERRED: "System for Generating a Dynamic Far Infrared Image," Patent granted 11 Dec 79, S/N: 41,178,514

COMMON NAME: Bly Cell, named by industry for its inventor, Vincent T. Bly

BACKGROUND: The importance of far-infrared technology to military and industrial system applications is continually increasing. However, the test technology available for effectively evaluating these systems has not kept up to that available for visible and near-infrared systems. There have been no techniques available for the simulation of high resolution, wide field-of-view dynamic imagery in the far-infrared region of the spectrum.

THE BLY CELL CONCEPT: The Bly Cell, a concept developed at the NV&EOL, is a new approach to simulation. It provides a simple low-cost system that has the high resolution and dynamic range necessary for laboratory infrared-image simulation. This concept offers industry a simulation capability substantially superior to those previously available.

HOW DOES IT WORK: The key element is a passive visible to far-infrared converter (or transducer) which approximates an infinitely thin blackbody membrane in a vacuum. The radiant energy of a visible image, projected into one side, is locally absorbed by the membrane and is re-emitted from both sides in the infrared. Although, this concept has been known for some time, its practical implementation has been limited by problems associated with time response, lateral-image spread, and conversion efficiency. Since practical transducers are not infinitely thin, they allow significant lateral heat diffusion which degrades resolution and possess a finite heat capacity which limits time response. The introduction of additional heat sinking by conduction or convection improves the time constant and resolution and increases the visible power required for a given infrared output. The Bly Cell uses a transducing film that is more than one order of magnitude thinner than those previously used. It is sufficiently thin that high resolution and fast time response are achieved without additional heat sinking.

INDUSTRIAL APPLICATIONS: Martin Marietta Aerospace, Orlando Division, Florida, in collaboration with V. Bly, produced the first working model which proved its feasibility. This model was applied in the development of a direct cathode ray to IR-conversion display for boresighting infrared and visible systems. Hughes Aircraft Company, Engineering Laboratories, Tucson, Arizona, subsequently used this concept in the development of apparatus for the testing of missile seekers in conjunction with the Defense Advanced Research Projects Agency (DARPA) Advanced IR Seeker and the Air Force Maverick IR Guidance System.

FUTURE: The Eppley Laboratories, Newport, R.I., realizing the Bly Cells' practibility as a laboratory tool, have begun commercialization of the device for industrial applications.

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